candle at different distances ($2\frac{1}{2}$ and $3\frac{1}{2}$ metres) from the selenium gave tolerably concordant results when calculated on the supposition that the effect upon the selenium varies as the square root of the light intensity. The influence of about 350 square centimetres of the *luminous sheet* on the selenium was found equal to that of 0·0014 standard candle, or 0·04 standard candle per square metre.

In conclusion I wish to remark that the above must be considered only as preliminary experiments, and the figures given as only approximate. I am now engaged in making further experiments on this subject with the endeavour to obtain more accurate results and to extend these researches, as it seems probable that the sensitive selenium plate may render similar services to the study of phosphorescent light as the thermopile has rendered to the study of radiant heat. EUGEN OBACH

AGRICULTURAL CHEMISTRY[1]

II.

IT has been shown that the plant may receive abundance of nitrogen, may produce abundance of chlorophyll, and may be subject to the influence of sufficient light, and yet not assimilate a due amount of carbon. On the other hand, it has been seen that the mineral constituents may be liberally provided, and yet, in the absence of a sufficient supply of nitrogen in an available condition, the deficiency in the assimilation of carbon will be still greater. In fact, assuming all the other necessary conditions to be provided, it was seen that the amount of carbon assimilated depended on the available supply of nitrogen.

In a certain general sense it may be said that the success of the cultivator may be measured by the amount of carbon he succeeds in accumulating in his crops. And as, other conditions being provided, the amount of carbon assimilated depends on the supply of nitrogen in an available form within the reach of the plants, it is obvious that the question of the sources of the nitrogen of vegetation is one of first importance. Are they the same for all descriptions of plants? Are they to be sought entirely in the soil, or entirely in the atmosphere, or partly in the one and partly in the other?

These are questions which Mr. Lawes and myself have discussed so frequently that it might seem some apology was due for recurring to the subject here, especially as I considered it in some of its aspects before this Section at the Sheffield meeting last year. But the subject still remains one of first importance to agriculture, and it could not be omitted from consideration in such a review as I have undertaken to give. Moreover, there are some points connected with it still unsettled, and some still disputed.

It will be remembered that De Saussure's conclusion was that plants did not assimilate the free or uncombined nitrogen of the atmosphere, and that they derived their nitrogen from the compounds of it existing in the atmosphere, and especially in the soil. Liebig, too, concluded that plants do not assimilate nitrogen from the store of it existing in the free or uncombined state, but that ammonia was their main source, and he assumed the amount of it annually coming down in rain to be much more than we now know to be the case.

Referring to our previous papers for full details respecting most of the points in question, I will state, as briefly as I can, the main facts known—first in regard to the amount of the measurable, or as yet measured, annual deposition of combined nitrogen from the atmosphere; and secondly as to the amount of nitrogen annually assimilated over a given area by different crops—so that some judgment may be formed as to whether the measured atmospheric sources are sufficient for the requirements of agricultural production, or whether, or where we must look for other supplies?

First, as to the amount of combined nitrogen coming down as ammonia and nitric acid in the measured aqueous deposits from the atmosphere.

Judging from the results of determinations made many years ago, partly by Mr. Way, and partly by ourselves, in the rain, &c., collected at Rothamsted; from the results of numerous determinations made much more recently by Prof. Frankland in the deposits collected at Rothamsted, and also in rain collected elsewhere; from the results obtained by Boussingault in Alsace; from those of Marié-Davy at the Meteorological Observatory at Montsouris, Paris; and from those of many others made in France and Germany—we concluded, some years ago, that the amount of combined nitrogen annually so coming down from the atmosphere would not exceed 8 or 10 lbs. per acre per annum in the open country in Western Europe. Subsequent records would lead to the conclusion that this estimate is more probably too high than too low. And here it may be mentioned in passing, that numerous determinations of the nitric acid in the drainage water collected from land at Rothamsted, which had been many years unmanured, indicate that there may be a considerable annual loss by the soil in that way; indeed, probably sometimes much more than the amount estimated to be annually available from the measured aqueous deposits from the atmosphere.

It should be observed, however, that the amount of combined nitrogen, especially of ammonia, is very much greater in a given volume of the minor aqueous deposits than it is in rain; and there can be no doubt that there would be more deposited within the pores of a given area of soil than on an equal area of the non-porous even surface of a rain-gauge. How much, however, might thus be available beyond that determined in the collected and measured aqueous deposits, the existing evidence does not afford the means of estimating with any certainty.

The next point to consider is—What is the amount of nitrogen annually obtained over a given area, in different crops, when they are grown without any supply of it in manure? The field experiments at Rothamsted supply important data relating to this subject.

Thus, over a period of 32 years (up to 1875 inclusive), wheat yielded an average of 20·7 lbs. of nitrogen per acre per annum, without any manure; but the annual yield has declined from an average of more than 25 lbs. over the first 8, to less than 16 lbs. over the last 12, of those 32 years; and the yield (it is true with several bad seasons) has been still less since.

Over a period of 24 years barley yielded 18·3 lbs. of nitrogen per acre per annum, without any manure; with a decline from 22 lbs. over the first twelve, to only 14·6 lbs. over the next 12 years.

With neither wheat nor barley did a complex mineral manure at all materially increase the yield of nitrogen in the crops.

A succession of so-called "root-crops"—common turnips, Swedish turnips, and sugar-beet (with 3 years of barley intervening after the first 8 years)—yielded, with a complex mineral manure, an average of 26·8 lbs. of nitrogen per acre per annum over a period of 31 years. The yield declined from an average of 42 lbs. over the first eight years, to only 13·1 lbs. (in sugar-beet) over the last 5 of the 31 years; but it has risen somewhat during the subsequent 4 years, with a change of crop to mangolds.

With the leguminous crop, beans, there was obtained, over a period of 24 years, 31·3 lbs. of nitrogen per acre per annum without any manure, and 45·5 lbs. with a complex mineral manure, including potass (but without nitrogen). Without manure the yield declined from 48·1 lbs. over the first 12 years to only 14·6 lbs. over the last 12; and with the complex mineral manure it declined from 61·5 lbs. over the first 12, to 29·5 lbs. over the last 12, years of the 24.

Again, an ordinary rotation of crops of turnips, barley, clover, or beans, and wheat, gave, over a period of 28 years, an average of 36·8 lbs. of nitrogen per acre per annum without any manure, and of 45·2 lbs. with superphosphate of lime alone, applied once every four years, that is for the root crop. Both without manure, and with superphosphate of lime alone, there was a considerable decline in the later courses.

A very remarkable instance of nitrogen yield is the following—in which the results obtained when barley succeeds barley that is when one gramineous crop succeeds another, are contrasted with those when a leguminous crop, clover, intervenes between the two cereal crops. Thus, after the growth of six grain crops in succession by artificial manures alone, the field so treated was divided, and, in 1873, on one half barley, and on the other half clover, was grown. The barley yielded 37·3 lbs. of nitrogen per acre, but the three cuttings of clover yielded 151·3 lbs. In the next year, 1874, barley succeeded on both the barley and the clover portions of the field. Where barley had previously been grown, and had yielded 37·3 lbs. of nitrogen per acre, it now yielded 39·1 lbs.; but where the clover had previously been grown, and had yielded 151·3 lbs. of nitrogen, the barley succeeding it gave 69·4 lbs., or 30·3 lbs. more after the removal of 151·3 lbs. in clover, than after the removal of only 37·3 lbs. in barley.

[1] Opening Address in Section B (Chemical Science), at the Swansea meeting of the British Association, by J. H. Gilbert, Ph.D., F.R.S., V.P.C.S., F.L.S., President of the Section. Continued from p. 476.

Nor was this curious result in any way accidental. It is quite consistent with agricultural experience that the growth and removal of a highly nitrogenous leguminous crop should leave the land in high condition for the growth of a gramineous corn crop, which characteristically requires nitrogenous manuring; and the determinations of nitrogen in numerous samples of the soil taken from the two separate portions of the field, after the removal of the barley and the clover respectively, concurred in showing considerably more nitrogen, especially in the first nine inches of depth, in the samples from the portion where the clover had been grown, than in those from the portion whence the barley had been taken. Here then the surface soil at any rate had been considerably enriched in nitrogen by the growth and removal of a very highly nitrogenous crop.

Lastly, clover has now been grown for twenty-seven years in succession, on a small plot of garden ground which had been under ordinary garden cultivation for probably two or three centuries. In the fourth year after the commencement of the experiment, the soil was found to contain, in its upper layers, about four times as much nitrogen as the farm-arable-land surrounding it; and it would doubtless be correspondingly rich in other constituents. It is estimated that an amount of nitrogen has been removed in the clover crops grown, corresponding to an average of not far short of 200*l*. per acre per annum; or about ten times as much as in the cereal crops, and several times as much as in any of the other crops, growing on ordinary arable land; and, although the yield continues to be very large, there has been a marked decline over the second half of the period compared with the first. Of course, calculations of the produce of a few square yards into quantities per acre can only be approximately correct. But there can at any rate be no doubt whatever that the amount of nitrogen annually removed has been very great; and very far beyond what it would be possible to attain on ordinary arable land; where, indeed, we have not succeeded in getting even a moderate growth of clover for more than a very few years in succession.

One other illustration should be given of the amounts of nitrogen removed from a given area of land by different descriptions of crop, namely, of the results obtained when plants of the gramineous, the leguminous, and other families, are growing together, as in the mixed herbage of grass-land.

It is necessary here to remind you that gramineous crops grown separately on arable land, such as wheat, barley, or oats, contain a comparatively small percentage of nitrogen, and assimilate a comparatively small amount of it over a given area. Yet nitrogenous manures have generally a very striking effect in increasing the growth of such crops. The highly nitrogenous leguminous crops (such as beans and clover), on the other hand, yield, as has been seen, very much more nitrogen over a given area, and yet they are by no means characteristically benefited by direct nitrogenous manuring; whilst, as has been shown, their growth is considerably increased, and they yield considerably more nitrogen over a given area under the influence of purely mineral manures, and especially of potass manures. Bearing these facts in mind, the following results, obtained on the mixed herbage of grass land, will be seen to be quite consistent.

A plot of such mixed herbage, left entirely unmanured, gave over twenty years an average of 33 lbs. of nitrogen per acre per annum. Over the same period another plot, which received annually a complex mineral manure, including potass, during the first six years, but excluding it during the last fourteen years, yielded 46·3 lbs. of nitrogen; whilst another, which received the mixed mineral manure, including potass, every year of the twenty, yielded 55·6 lbs. of nitrogen per acre per annum. Without manure there was some decline of yield in the later years; with the partial mineral manuring there was a greater decline; but with the complete mineral manuring throughout the whole period, there was even some increase in the yield of nitrogen in the later years.

Now, the herbage growing without manure comprised about fifty species, representing about twenty natural families; that growing with the limited supply of potass comprised fewer species, but a larger amount of the produce, especially in the earlier years, consisted of leguminous species, and the yield of nitrogen was greater. Lastly, the plot receiving potass every year yielded still more leguminous herbage, and, accordingly, still more nitrogen.

The most striking points brought out by the foregoing illustrations are the following:—

1. Without nitrogenous manure, the gramineous crops annually yielded, for many years in succession, much more nitrogen over a given area than is accounted for by the amount of combined nitrogen annually coming down in the measured aqueous deposits from the atmosphere.

2. The root crops yielded more nitrogen than the cereal crops, and the leguminous crops very much more still.

3. In all cases—whether of cereal crops, root crops, leguminous crops, or a rotation of crops—*the decline in the annual yield of nitrogen, when none was supplied, was very great.*

How are these results to be explained? Whence comes the nitrogen? and especially whence comes the much larger amount taken up by plants of the leguminous and some other families, than by the gramineæ? And lastly, what is the significance of the great decline in the yield of nitrogen in all the crops when none is supplied in the manure?

Many explanations have been offered. It has been assumed that the combined nitrogen annually coming down from the atmosphere is very much larger than we have estimated it, and that it is sufficient for all the requirements of annual growth. It has been supposed that "broad-leaved plants" have the power of taking up nitrogen in some form from the atmosphere, in a degree, or in a manner not possessed by the narrow-leaved gramineæ. It has been argued that, in the last stages of the decomposition of organic matter in the soil, hydrogen is evolved, and that this nascent hydrogen combines with the free nitrogen of the atmosphere, and so forms ammonia. It has been suggested that ozone may be evolved in the oxidation of organic matter in the soil, and that, uniting with free nitrogen, nitric acid would be produced. Lastly, it has by some been concluded that plants assimilate the free nitrogen of the atmosphere, and that some descriptions are able to do this in a greater degree than others.

We have discussed these various points on more than one occasion; and we have given our reasons for concluding that none of the explanations enumerated can be taken as accounting for the facts of growth.

Confining attention here to the question of the assimilation of free nitrogen by plants, it is obvious that, if this were established, most of our difficulties would vanish. This question has been the subject of a great deal of experimental inquiry, from the time that Boussingault entered upon it, about the year 1837, nearly up to the present time. About twenty years ago it was elaborately investigated at Rothamsted. In publishing the results of that inquiry those of others relating to it were fully discussed; and although the recorded evidence is admittedly very conflicting, we then came to the conclusion, and still adhere to it, that the balance of the direct experimental evidence on the point is decidedly against the supposition of the assimilation of free nitrogen by plants. Indeed, the strongest argument we know of in its favour is, that some such explanation is wanted.

Not only is the balance of direct experimental evidence against the assumption that plants assimilate free or uncombined nitrogen, but it seems to us that the balance of existing indirect evidence is also in favour of another explanation of our difficulties.

I have asked what is the significance of the gradual decline of produce of all the different crops when continuously grown without nitrogenous manure? It cannot be that, in growing the same crop year after year on the same land, there is any residue left in the soil that is injurious to the subsequent growth of the same description of crop; for (excepting the beans) more of each description of crop has been grown year after year on the same land than the average yield of the country at large under ordinary rotation, and ordinary treatment—provided only that suitable soil conditions were supplied. Nor can the diminishing produce, and the diminishing yield of nitrogen, be accounted for on the supposition that there was a deficient supply of available mineral constituents in the soil. For, it has been shown that the cereals yielded little more, and declined nearly as much as without manure, when a complex mineral manure was used, such as was proved to be adequate when available nitrogen was also supplied. So far as the root crops are concerned the yield of nitrogen, though it declined very much, was greater at first, and on the average, than in the case of the cereals. As to the leguminosæ, which require so much nitrogen from somewhere, it is to be observed that on ordinary arable land the yield has not been maintained under any conditions of manuring; and the decline was nearly as marked with mineral manures as without any manure. Compared with the growth of the leguminosæ on arable land, the remarkable result with the garden clover would seem clearly to indicate that the question was one of soil, and

not of atmospheric supply. And the fact that all the other crops will yield full agricultural results even on ordinary arable land, when proper manures are applied, is surely very strong evidence that it is with them, too, a question of soil, and not of atmospheric supply.

But we have other evidence leading to the same conclusion. Unfortunately we have not reliable samples of the soil of the different experimental fields taken at the commencement of each series of experiments, and subsequently at stated intervals. We have nevertheless, in some cases, evidence sufficient to show whether or not the nitrogen of the soil has suffered diminution by the continuous growth of the crop without nitrogenous manure.

Thus we have determined the nitrogen in the soil of the continuously unmanured wheat plot at several successive periods, and the results prove that a gradual reduction in the nitrogen of the soil is going on; and, so far as we are able to form a judgment on the point, the diminution is approximately equal to the nitrogen taken out in crops; and the amount estimated to be received in the annual rainfall is approximately balanced by the amount lost by the land as nitrates in the drainage water.

In the case of the continuous root-crop soil, on which the decline in the yield of nitrogen in the crop was so marked, the percentage of nitrogen, after the experiment had been continued for twenty-seven years, was found to be lower where no nitrogen had been applied than in any other arable land on the farm which has been examined.

In the case of the experiments on the mixed herbage of grass land, the soil of the plot which, under the influence of a mixed mineral manure, including potass, had yielded such a large amount of leguminous herbage and such a large amount of nitrogen, showed, after twenty years, a considerably lower percentage of nitrogen than that of any other plot in the series.

Lastly, determinations of nitrogen in the garden soil which has yielded so much nitrogen in clover, made in samples collected in the fourth and the twenty-sixth years of the twenty-seven of the experiments, show a very large diminution in the percentage of nitrogen. The diminution, to the depth of 9 inches, only represents approximately three-fourths as much as the amount estimated to be taken out in the clover during the intervening period; and the indication is that there has been a considerable reduction in the lower depths also. It is to be supposed however that there would be loss in other ways than by the crop alone.

I would ask, Have we not in these facts—that full amounts of the different crops can be grown, provided proper soil conditions are supplied; that without nitrogenous manure the yield of nitrogen in the crop rapidly declines; and that, coincidently with this, there is a decline in the percentage of nitrogen in the soil—have we not in these facts cumulative evidence pointing to the soil, rather than to the atmosphere, as the source of the nitrogen of our crops?

In reference to this point I may mention that the ordinary arable soil at Rothamsted may be estimated to contain about 3,000 lbs. of nitrogen per acre in the first nine inches of depth, about 1,700 lbs. in the second nine inches, and about 1,500 lbs. in the third nine inches—or a total of about 6,200 lbs. per acre to the depth of twenty-seven inches.

In this connection it is of interest to state that a sample of Oxford clay obtained in the sub-Wealden exploration boring, at a depth of between 500 and 600 feet (and which was kindly given to me by the President of the Association, Prof. Ramsay, some years ago), showed, on analysis at Rothamsted, approximately the same percentage of nitrogen as the subsoil at Rothamsted taken to the depth of about 4 feet only.

Lastly, in a letter received from Boussingault some years ago, referring to the sources whence the nitrogen of vegetation is derived, he says:—

"From the atmosphere, because it furnishes ammonia in the form of carbonate, nitrates, or nitrites, and various kinds of dust. Theodore de Saussure was the first to demonstrate the presence of ammonia in the air, and consequently in meteoric waters. Liebig exaggerated the influence of this ammonia on vegetation, since he went so far as to deny the utility of the nitrogen which forms a part of farmyard manure. This influence is nevertheless real, and comprised within limits which have quite recently been indicated in the remarkable investigations of M. Schlösing.

"From the soil, which, besides furnishing the crops with mineral alkaline substances, provides them with nitrogen, by ammonia, and by nitrates, which are formed in the soil at the expense of the nitrogenous matters contained in diluvium, which is the basis of vegetable earth; compounds in which nitrogen exists in stable combination, only becoming fertilising by the effect of time. If we take into account their immensity, the deposits of the last geological periods must be considered as an inexhaustible reserve of fertilising agents. Forests, prairies, and some vineyards, have really no other manures than what are furnished by the atmosphere and by the soil. Since the basis of all cultivated land contains materials capable of giving rise to nitrogenous combinations, and to mineral substances, assimilable by plants, it is not necessary to suppose that in a system of cultivation the excess of nitrogen found in the crops is derived from the free nitrogen of the atmosphere. As for the absorption of the gaseous nitrogen of the air by vegetable earth, I am not acquainted with a single irreproachable observation that establishes it; not only does the earth not absorb gaseous nitrogen, but it gives it off, as you have observed in conjunction with Mr. Lawes, as Reiset has shown in the case of dung, as M. Schlösing and I have proved in our researches on nitrification.

"If there is one fact perfectly demonstrated in physiology it is this of the non-assimilation of free nitrogen by plants; and I may add by plants of an inferior order, such as mycoderms and mushrooms (translation)."

If, then, our soils are subject to a continual loss of nitrogen by drainage, probably in many cases more than they receive of combined nitrogen from the atmosphere—if the nitrogen of our crops is derived mainly from the soil, and not from the atmosphere—and if, when due return is not made from without, we are drawing upon what may be termed the store of nitrogen of the soil itself—is there not, in the case of many soils at any rate, as much danger of the exhaustion of their available nitrogen as there has been supposed to be of the exhaustion of their available mineral constituents?

I had hoped to say something more about soils to advance our knowledge respecting which an immense amount of investigation has been devoted of late years, but in regard to which we have yet very much more to learn. I must however now turn to other matters.

(To be continued.)

IMPROVED HELIOGRAPH OR SUN SIGNAL[1]

THE author claims to have contrived a heliograph, or sun telegraph, by which the rays of the sun can be directed on any given point with greater ease and certainty than by those at present in use.

When the sun's rays are reflected at a small plane surface considered as a point, the reflected rays form a cone, whose vertex is at the reflector and whose vertical angle is equal to that subtended by the sun. Adding to the size of the mirror adds other cones of light, whose bounding rays are parallel with those proceeding from other points of the mirror, and only distant from them the same distance as the points on the mirror from which they are reflected. Hence increasing the size of the mirror only adds to the field to which the sun's rays are reflected a diameter equal to the diameter of the mirror, and this at any distance at which the sun signal would be used is quite inappreciable. Adding to the size of the mirror adds to the number of rays sent to each point, and hence to the brightness of the visible flash, but not to the area over which it is visible.

By the author's plan an ordinary field-glass is used to find the position of the object to be signalled to, and to it is attached, in the position of the ordinary sun-shade, a small and light apparatus, so arranged that when the mirror is turned to direct the cone of rays to any object within the field view of the glass, an image of the sun appears in the field, at the same time as the image of the distant object, and magnified to the same degree, and the part of the field covered by this image is exactly that part to which the rays are reflected, and at which some part of the sun's disk is visible in the mirror.

A perfectly plane silvered mirror, *A*, takes up the rays of the sun, and when in proper position reflects them parallel with the axis of *D*, which is one barrel of an ordinary field-glass. The greater part of the light passes away to the distant object, but some is taken up by the small silvered mirror, *E*, which is placed at an angle of 45° to the axis of *D*, and reflected at a right angle through the unsilvered plane mirror, *F*, and the convex lens, *K*, by which it is brought to a focus on the white

[1] Paper read at the British Association by Tempest Anderson, M.D., B.Sc.